layer; an N− SiC collector; and an N+ SiC collector, all disposed on an N+ or semi-insulating Si collector substrate.

[0158] As seen from the conduction band diagram in FIG. **6**B, hot electrons can be injected from the N+ polysilicon emitter, travel through an emission barrier formed by the optional P-type polysilicon layer, and enter into the graphene material base layer. The electrons then traverse the base layer and enter the SiC collectors optionally as hot electrons, depending on the energy of the electrons in the base layer, and then thermalize to the SiC conduction band minimum to be non-hot electrons in the SiC. There is a built-in conduction band offset at the interface of the N− SiC collector with the graphene due to the electron affinity difference between graphene and SiC that the hot electrons in the graphene base must overcome to enter into the collector.

FIGS. 7A-7B: N+ GaN or N+ AlGaN Emitter.

[0159] As shown in FIG. **7**A, a transistor device in accordance with this embodiment of the present invention can have an N+ GaN or N+ AlGaN emitter; an optional emitter transition layer made from MN, AlGaN, and/or GaN to form a graded thermionic emission barrier injection structure, tunnel barrier injection structure, Fowler Nordheim injection structure, or resonant tunneling injection structure; a transferred and bonded graphene material base layer; an optional GaN or AlGaN collector transition layer; an N− GaN or AlGaN collector; and an N+ GaN or AlGaN collector, all disposed on a GaN, SiC, silicon, or sapphire substrate.

[0160] As seen from the conduction band diagram in FIG. **7**B, hot electrons can be injected from the N+ GaN or N+ AlGaN emitter, travel through an emission barrier injection structure formed by the optional MN, AlGaN, and/or GaN layer, and enter the graphene material base layer. The electrons then traverse the base layer may enter the collectors optionally as hot electrons as described above, with the N− GaN or AlGaN collector providing a built-in conduction band offset due to the electron affinity difference between graphene and GaN or AlGaN layer.

FIGS. 8A-8B: N+ InGaAs Emitter.

[0161] As shown in FIG. **8**A, a transistor device in accordance with this embodiment of the present invention can have an N+ InGaAs or other appropriate semiconductor emitter; an optional InGaAs graded thermionic emission barrier injection structure, tunnel barrier injection structure, Fowler Nordheim injection structure, or resonant tunneling injection structure; a transferred and bonded graphene material base layer; an optional InGaAs collector transition layer; an N—InP or InGaAs collector; and an N+ InP or InGaAs collector, all disposed on a GaN, SiC, silicon, or sapphire substrate.

[0162] As seen from the conduction band diagram in FIG. **8**B, hot electrons can be injected from the N+ InGaAs or other appropriate semiconductor emitter, travel through an emission barrier formed by the optional InGaAs layer, and enter the graphene material base layer. The electrons then traverse the base layer and may enter the collectors optionally as hot electrons as described above, with the InP or InGaAs collector providing a built-in conduction band offset due to the electron affinity difference between graphene and SiC.

[0163] FIGS. **9**A-**9**B: N+ InGaAs Emitter with Graphene Collector.

[0164] As shown in FIG. **9**A, a transistor device in accordance with this embodiment of the present invention can have an N+ InGaAs or other appropriate semiconductor emitter; an optional InGaAs graded thermionic emission barrier injection structure, tunnel barrier injection structure, Fowler Nordheim barrier injection structure, or resonant tunneling injection structure; a transferred and bonded graphene material base layer; and an N− type graphene collector, all disposed on an N+ type substrate or ohmic material.

[0165] As seen from the conduction band diagram in FIG. **9**B, hot electrons can be injected from the N+ InGaAs or other appropriate semiconductor emitter, travel through an emission barrier formed by the optional InGaAs layer, and enter the graphene material base layer. The electrons then traverse the base layer and may enter optionally as hot or ballistic electrons into the N+ graphene collector.

[0166] FIGS. **10**A-**10**B and **11**A-**11**B depict aspects of exemplary embodiments of a graphene base transistor for non-hot electron injection in accordance with the present invention.

FIGS. **10**A-**10**B: N+ InGaAs emitter with graphene collector.

[0167] As shown in FIG. **10**A, a transistor device in accordance with this embodiment of the present invention can have an N+ emitter comprising, for example, one of the SMNHEI materials described above; a P-type graphene material base layer that is transferred from a graphene CVD growth on a metal substrate or a graphene epitaxial growth on a SiC substrate; an optional collector transition layer made up of a graded bandgap material to reduce barrier height, if any, at the graphene/collector interface; an N-type collector formed from one or more of CdSe, InAs, SnO2:F, InSb, ZnO, BN, CdTe, CdS, In2O3:Sn, InGaN, InAsP, InP, InGaAs, InAlAs, InGaSb, graphene, and diamond material layers material layers, all disposed on a substrate that is contacted by an ohmic metal electrode connection. Alternately, a Schottky metal electrode connection an be made to the N-type collector layer.

[0168] As seen from the conduction band diagram in FIG. **10**B, electrons can be injected from the N+ emitter as non-hot electrons having an energy E less than that of the conduction band minimum of the graphene material base layer. The non-hot electrons are transported through the base by diffusive transport, ballistic transport, and/or coherent transport and enter optionally as hot electrons into the collector.

[0169] FIGS. **11**A-**11**B: N+ InGaAs Emitter with Graphene Collector.

[0170] As shown in FIG. **11**A, a transistor device in accordance with this embodiment of the present invention can have an N+ emitter comprising, for example, one of the SMNHEI materials described above; P-type graphene material base layer that is transferred from a graphene CVD growth on a metal substrate or a graphene epitaxial growth on a SiC substrate-; an optional collector transition layer made up of a graded bandgap material to reduce barrier height, if any, at the graphene/collector interface; an N-type collector formed from N-type graphene that is contacted by an ohmic metal electrode connection. Only a small reverse bias voltage can be applied between graphene base and graphene collector because of small bandgap (in the case of bi-layer graphene or doped graphene) or no bandgap (in the case of single-layer graphene) of a graphene material layer. The electrons in the collector can have ballistic transport for a short distances into the graphene collector